

# **The Atom Will Be Split Anew**

## **Naturally and Safely**

### **Share of various countries in the production of nuclear energy:**

United States (97,145 Megawatts)	28%
France (63,103 Megawatts)	18%
Japan (43,691 Megawatts)	12.5%
Russia (19,843 Megawatts)	5.5%
Germany (21,122 Megawatts)	6%
South Korea (12,990 Megawatts)	4%
Ukraine (12,155 Megawatts)	3.5%
Others (79,014 Megawatts)	22.5%

According to data from MINATOM, Russian Federation.

**The energy crises in the Primore and California and also the predicted shortages in Europe and Asia have already forced the governments of Russia, the United States, and other countries to rethink their energy programs. More simply put, the conversation is about the development of nuclear energy. The United States plans to bring 20 new nuclear power plants online in the next ten years. Russia has its own plan – “naturally safe” nuclear energy embodied in the BREST reactor.**

### **NUCLEAR GENERATIONS**

Practically all active nuclear energy complexes in the world today have their origin in military nuclear technology. Physicists, having learned to use a nuclear chain reaction for explosions, weapons grade plutonium and nuclear submarines, used this as the basis for developing reactors for peaceful nuclear energy.

In 1954, in the Moscow suburban Obninsk, the first nuclear power plant in the world started operation with uranium fuel and graphite moderators. The first two domestic commercial blocks at the Beloyarsk Nuclear Power Plant in the Sverdlovsk Oblast operated using approximately this same principle. They were put into operation ten years afterwards. These reactors, in essence, were the predecessors of the RBMK pressure tube design reactors, which were developed in the Moscow Scientific Research and Construction Institute (NIKIET) and appeared at the Leningrad Nuclear Power Plant in 1973.

Similar reactors were used to refine weapons-grade plutonium for bombs and were also able to produce electricity. Their shortcoming was that the reactor was not enclosed in a concrete cupola and in the event of a major disaster; nuclear materials would be spread outside as happened at the Chernobyl Nuclear Power Plant. After the catastrophe, NIKIET refined its design, enclosing the reactor in a “cone” and called this design MKER. But the modernized reactor remained on paper – Chernobyl halted the development of domestic nuclear power.

Parallel with the development of graphite reactors in the USSR came the development of other nuclear projects, based on the reactors of nuclear submarines. These were the so-called light water reactors, VVER – offspring of the favorable OKB “Hydropress”. There is no graphite in the VVER reactors; neutrons are slowed in these reactors by water, which at the same time cools the fuel. Unlike RBMK reactors, light water reactors are sealed under pressure. The first blocks of this type were built at the Novovoronezhsk Nuclear Power Plant in 1964 and the following years.

The development of nuclear energy abroad took practically the same path as in the USSR. In 1956 in Great Britain, the first nuclear power plant “Colder Hall” began operation with a graphite reactor “Magnox”, named for the type of fuel used in it (uranium with a shell of magnesium and beryllium). Similar reactors were used in France. Cooling in these reactors took place using carbon dioxide, but these reactors had much in common with the Soviet RBMK reactors. It is true that after that, European countries followed the path of the United States, and used light water reactors.

In 1958, the United States started its first nuclear power plant “Shippingport” with light water reactors, which until then were used on nuclear submarines. Light water reactors, classified in the western system as PWR or their boiling variant BWR became, from that time, the basis for the development of all world nuclear energy – in France, Great Britain, Germany, Japan, and Korea. Incidentally, all of the first overseas reactors also had no domes. Western nuclear physicists joked that a cupola would be built over a reactor at the insistence of architects to make the industrial landscape look fashionable. But in one way or another, the PWR began to be covered with a dome.

The correctness of this “designer decision” was supported during the disaster at the American station “Three Mile Island” in 1979. By its strength, the disaster was less than that of Chernobyl, but the dome contained the leakage from the reactor and saved the people and territory from radioactive contamination.

Today, 90% of all nuclear power plants in the world use light water reactors. The remaining 10% - that is the Russian RBMK (half of the 30 operational energy blocks in the Russian Federation) and the Canadian “Candu” reactors. The last energy blocks are also of the pressure tube design variety, although they use heavy water as a moderator instead of graphite. Unlike the RBMK and VVER reactors, where the fuel is enriched uranium, the “Candu” can use natural uranium and therefore is used in countries that don’t have the capability to produce enriched uranium (for example, India).

## **DIET FOR A REACTOR**

According to experts, there is one very real flaw in current world nuclear energy with its thermal reactors. It runs on Uranium-235, which occurs in natural uranium in a concentration of only 0.7%. Therefore for thermal nuclear energy, there is enough raw material from the rich deposits to constitute only one ten millionth of all the world’s uranium reserves. The amount of uranium in the discovered rich deposits is estimated at approximately 5 million tons, and potentially a little over 10 million tons. Going by today’s usage of uranium in thermal reactors, these resources could disappear by the end of the 21<sup>st</sup> century both in Russia and in the world as a whole.

Even in the 40s, physicists understood the shortcomings of thermal reactors that grew from nuclear weapons. Enrico Fermi, who in 1942 started the first reactor for

military purposes, proposed building a principally new design – a fast neutron reactor (BN). The difference from a thermal reactor is that in them, there is an expanded reproduction of fuel. That is, they use less fuel than they produce. The effectiveness of use of uranium in nuclear energy in this situation multiplies a hundred times. Therefore, fuel from poor deposits can be used, and these deposits are inexhaustible.

However, the BN reactor also has its shortcomings. Along with the fast reactors, you must deal with the production of spent nuclear fuel (OYaT) and plutonium that can be extracted from that spent fuel for reuse. From the point of view of clean energy, this is not a shortcoming; on the contrary, it is a great plus. The extracted plutonium can be mixed with uranium and reused as a fuel in a nuclear power plant. What results is an effective and economical closed nuclear cycle. However, plutonium from nuclear stations with BN reactors poses a threat to the regime of nonproliferation of weapons technology. For compliance with the regime, there must be technological and political barriers. (More simply put, if the goal is to acquire plutonium, it may be extracted from the spent fuel of light water reactors; plutonium makes up about 1% of spent fuel of thermal reactors).

The first fast neutron reactor tested was in the United States in 1952. However, an accident with it occurred soon after. The next BN reactor that was built was more powerful, but it suffered an accident during startup. Subsequently the United States stopped the operation of fast reactors, believing them not to be safe enough from the point of proliferation of weapons technology. The USSR and Russia surpassed both the United States and other countries in the technology of fast reactors. The BR-5 reactor in Obninsk which was started in 1958 and the BOR-60 reactor in Dimitrovgrad started in 1968 both operate to this day. Soviet nuclear science built, with great success, an industrial fast reactor in Shevchenko, Kazakhstan in 1972.

The industrial fast neutron reactor BN-600 was built in 1980. The second life of the Belayarsk Nuclear Power Plant, at which two energy blocks with thermal reactors ran previously, began with this reactor. These reactors have been decommissioned.

In France, the first BN “Phoenix” reactor was started in 1974 and in 1983, the “Super Phoenix” was built, but is currently shut down because of technical and financial problems. Even Japan tried to start its own nuclear power plant with a BN reactor through its project “Monzhu”. However there was an accident and it stands idle to this day. India already has one fast reactor and is building a second. China is also starting to build such a block.

## **AFTER CHERNOBYL**

After the catastrophes at “Three Mile Island” and Chernobyl, development of nuclear energy in the world slowed noticeably. Politicians didn’t want to point out the potential safety risks of energy production; what’s more, the more developed countries were experiencing no shortage of traditional types of fuel. According to the prediction of experts, there will be no shortage of traditional fuels for many decades. But scientists believe that work on new generation nuclear stations is necessary today, otherwise this work will have to be begun from nothing in the future.

An overriding agreement on which path to take in the development of the future of atomic energy in the world still does not exist. Judging from everything, the

specialists from the various countries, for one reason or another are standing at a crossroads and are unable to choose a direction in which to go.

The United States has put forth an initiative for an international project called Generation Four. One of the ideas of this project was to create a small reactor which could be transported fully assembled to another country and left for approximately ten years without refueling and then returned home. In this way, the problem of nonproliferation would be resolved. But for many of the major countries, such a system is unacceptable, as it places them completely at the mercy of the manufacturer of the nuclear power plant.

France, where 80% of the electricity is produced at a nuclear power plant, is now studying the possibility of producing a fast reactor in which cooling would be accomplished using helium. Similar research took place in Russia and was declared unworkable because the use of helium could cause an accident from helium leakage.

The greatest interest in new sources of energy is appearing now in the Asian countries, which do not want to be dependent on other governments and intend to develop their own nuclear energy. Nuclear power plants are being built in Japan, Korea, China, Iran, Pakistan, and India. The Asian countries don't use their own original designs, but prefer to follow a well-trodden path.

Recently a certain revival has appeared in Russian nuclear fields; this year the Rostovsk Station was started, and the secret post-Chernobyl moratorium on the startup of new nuclear power plants was suspended. Exactly a year ago, the government adopted a strategy for development of domestic nuclear energy, which intends to start 30 energy blocks in the next 30 years. Construction on many of these began before Chernobyl and was halted. In this document, it is written that the energy of the future, "can find its place in many types of reactors" – thermal and fast neutron playing the dominating role in the past. This strategy was adopted when the Russian Ministry of Atomic Energy was headed by Yevgenij Adamov, a staunch advocate of the development of such fast reactors. Two months ago, Mr. Adamov was replaced as the head of MINATOM by Aleksandr Rumyantsev, who is inclined to support a variety of forms in nuclear energy. Now, it seems, there will not be a concentration of effort in a single direction, fast reactors.

## **COURSE TO BREST**

In the currently operating BN reactors, the coolant used is sodium, which is chemically active and bursts into flames when exposed to the air. In order to ensure the safety of such reactors, it is necessary to construct a complicated technical device that complicates construction and increases the cost. Sodium, by its physical characteristics, allows faster and more plentiful production of plutonium, which was good when there was a high tempo of energy growth and there was not enough plutonium.

Now the task is reversed: there is more than enough plutonium, and what's important is safety at an affordable price. In an effort to partly solve this problem, the BN 800 was modified. This reactor takes enriched fuel, more "dense". Together with the current dioxide of uranium and plutonium is a mononitride, that is, a mix with nitrogen. While burning such fuel, plutonium produces as much as it burns. The BN-800 facility,

which was built in the 80s at the Beloyarsk Nuclear Power Plant, has been renewed and is planned to be restarted by 2010.

The Scientific Director of Future Development for NIKIET, Chairman of the MINATOM Scientific-Technical Council on Nuclear Reactors, Victor Orlov believes that the next generation of fast reactors improves their principle characteristics. He explained that fuel in such a reactor is the same as in the BN-800, with nitrogen, however cooling would not be accomplished with sodium but with heavy metal – liquid lead. Similar reactors were used on eight Soviet nuclear submarines, but there a mix of lead and bismuth was used. It is necessary to restrict use to one – lead – for energy because bismuth is a quite rare material.

The new fast reactor project being worked on in NIKIET is known by the name BREST (fast reactor with lead cooling). There are also plans to build it at the Beloyarsk station: by 2007 as a test and demonstration reactor, a small, not-so-powerful BREST 300, and commercially after 2020 as a very powerful BREST 1200.

Mr. Orlov asserts that BREST is built on the principle of natural safety: assurance of reliability is achieved not by the number of new or by the refinement of already proven protective engineering barriers, but because of the fundamental physical and chemical characteristics of nuclear fuel, heat dissipaters and other components. The BREST reactor unit differs from any currently operating apparatus in construction design as well. The reactor is in a pool type unit; lead is poured into a pit of heat-isolating concrete, in which are the active zone, steam generator, pump, and other servicing systems. As Victor Orlov emphasizes, BREST is stable and does not exceed active means of automatic protection in an extreme emergency.

Among other prospective developments could be the thermal reactor that uses uranium-thorium fuel. It conserves uranium-235, but it needs a different isotope of this element – uranium-233, which does not occur in nature but can be produced in a BN reactor. That is, when the reserves of uranium-235 are depleted, fast reactors can supply the fuel for thermal blocks with uranium-thorium fuel.

It is possible that, in several decades, thermonuclear reactors could be included in energy production. Although they have made thermonuclear weapons, scientists have still not yet been able to achieve the technology to produce energy in a thermonuclear power plant. Currently several countries are conducting research on such an international reactor under the name ITER (International Thermonuclear Experimental Reactor).

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